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RESEARCH IN THE LAKE HAZEN REGION OF NORTHERN ELLESMERE ISLAND IN THE I.G.Y.[1]

By G. Hattersley-Smith[2]

"Operation Hazen" was organized by the Defence Research Board, to carry out meteorological, glaciological, geophysical and geological investigations in the Lake Hazen region of northern Ellesmere Island during two summers and one winter, 1957-58. Biological and archaeological work was also undertaken by officers of various Government departments in the summer of 1958. The organization was entrusted to the Defence Research Board Geophysics Section, which is headed by Mr. T.A. Harwood. The present writer was in charge of the operation in the field during the two summers, and Mr. C.R. Harington of McGill University was in charge of the wintering party.

Twenty scientists took part in the operation, including officers of the Fisheries Research Board, the Geological Survey, the Human History and Natural History Branches of the National Museum, and the Wildlife Service, and members of McGill University, the Universities of Toronto and Alberta, and Michigan State University. The following is a brief review of the logistic arrangements for the operation, and of the scientific work based on preliminary reports.[3]

The expedition was magnificently served by the R.C.A.F. Air Transport Command, 436 Squadron from Downsview, who provided the spring airlift in both years, and 408 Squadron from Rockcliffe, who provided airlift to the glacier in 1957; and by the Air Defence Command, 121 Communication and Rescue Flight from Sea Island, who provided airlift to the glacier and ice cap in 1958. In 1957, the airlift involved ten

[1] Published by permission of the Chairman, Defence Research Board of Canada.

[2] Geophysics Section, Defence Research Board.

[3] [Defence Research Board]. "Operation Hazen: narrative and preliminary reports for the 1957 season". Ottawa: January 1958, iii + 57 p., illus., maps.

"Operation Hazen: narrative and preliminary reports for 1957-58". Ottawa: March 1959, iv + 88 p., diagrs., maps.

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landings in late April and early May by C-119 ("Flying Boxcar") aircraft in transporting the party of eight, two tractors, two dogteams, and 35 tons of stores, fuel and equipment to Lake Hazen via Resolute and Thule Air Base. The first two landings were made on an unprepared strip. A bulldozer, carried in at the first landing, was used to prepare a 3,500-foot airstrip on the lake ice for subsequent landings. An airlift of similar proportion was carried out in 1958, in transporting the party of twenty, three dogteams and 30 tons of fuel and equipment. In addition a C-130A ("Hercules") aircraft of the United States Air Force, equipped with skis, brought in 9 tons of fuel at the end of March. In May 1957, the base camp, consisting of two Attwell shelters and a Jamesway hut, the latter taken over from the "Shoran" station on Johns Island, was established on the north shore of the lake, opposite Johns Island. The establishment of the camp on Gilman Glacier at 3,400 feet called for an airdrop by 436 Squadron and three landings by DC-3 ("Dakota") aircraft of 408 Squadron, whose Commanding Officer, W/C J.G. Showler, A.F.C., C.D., pilots and aircrew, went out of their way to assist the operation. The camp was reopened in 1958, when fourteen "Dakota" landings were made by 121 C. and R. Flight in connexion with manning and restocking the camp and flying parties to outlying field stations. Three pyramid tents, containing valuable equipment, which were pitched in August 1957, were found standing in excellent condition after the winter. The expedition was greatly indebted to F/L M.W. Utas, of 121 C. and R. Flight, and his aircrew - to his experienced judgment and skilful airmanship, and to the efficient teamwork of the crew. During the spring airlift in both years, valuable assistance was received from an experienced tractor driver/mechanic, Sgt. D. Engel, R.C.E., and in 1958 from an experienced radio technician, Sgt. J.E. Robertson, R.C.S.

In early June 1958, the Chairman of Defence Research Board, Dr. A.H. Zimmerman, and a party of senior Canadian and United States service officers and Government officials visited Lake Hazen for two days in a "North Star" aircraft, which used a 5,000-foot runway on the lake ice.

The 1957 summer party was relieved in mid-August by the winter party, who arrived at the head of Chandler Fiord in U.S.C.G.C. Eastwind. The transfer of the winter party and 15 tons of stores and fuel for the 1958 summer, and the evacuation of the summer party with two dogteams, specimens, records and certain equipment were effected by helicopter in 35 hours flying. Evacuation in mid-August 1958 was carried out by U.S.S. Atka. The expedition owed much to Capt. R.F. Rea, U.S.C.G., Cdr. W.H. Reinhardt, U.S.N., and ships' companies for their outstanding services. Five men, who remained behind to complete scientific work, were brought out by an R.C.A.F. "Canso" aircraft of 121 C. and R. Flight under the command of F/L E.M. Neil, on 20 August 1958. The airlift and sea-lift operations were most ably coordinated by L/Cdr. J.P. Croal, R.C.N., at that time seconded to the Defence Research Board. In early August 1958,

Dr. Terris Moore of North Vassalboro, Maine, visited Lake Hazen in his Piper "Super-Cub" aircraft which he had flown solo from the United States. He most kindly flew members of the expedition on a number of service and reconnaissance flights in the area.

During the 1957 summer, only two members of the party of eight were based on the lake; the remaining six worked from the Gilman Glacier camp throughout the summer. In the 1958 summer, thirteen members of the party of nineteen, including the four men who wintered, were based on the lake; the remaining six were based on the glacier. In 1958, twelve members of the party were working on Defence Research Board projects; the remaining seven were working for other Government departments. The work from the Lake Hazen base camp will be described first.

The winter party consisted of four graduates from McGill University, working under contract for Defence Research Board, Messrs. C.R. Harington, J.M. Powell, C.I. Jackson, and D.I. Smith. They successfully achieved their main objective, a complete record of synoptic meteorological observations. They also made studies on micro-meteorology, auroral activity, ice growth and snow cover on the lake, ground temperatures and local wildlife. Their year-long meteorological record is the first of its kind from an inland station north of the Canadian Arctic mainland. The mean temperature for December was -47.7°F., and the minimum temperature of the winter -68.5°F. The Lake Hazen trough proved to be a gigantic frost hollow with an intense surface inversion, with temperatures at the lake commonly 25°F. lower than at Alert. Cloud cover was very rarely below 1,000 feet, except in the month of September, and the 3,000-foot hills north of the camp were usually free of cloud. In September, the lake remained open for three weeks after the air temperature fell below freezing on the third of the month. This period was characterized by a local climate with an air temperature of about 20°F. and with a persistent layer of low stratus or strato-cumulus. After the lake froze, the temperature fell very rapidly. In the winter, ice crystal fog could cause difficulties in aircraft operations; ice fog did in fact persist for several hours after take-off of the C-130A aircraft in March. The mean annual temperature for 1957-58 was about -6°F.

In May 1958, as part of the Defence Research Board geophysical programme, absolute gravity stations were established at Lake Hazen, Ward Hunt Island, Clements Markham Inlet, Gilman Glacier and Fort Conger by Dr. F.S. Grant of the University of Toronto, working under contract for the Defence Research Board. These stations were tied into the Canadian-Greenland network by observations at Churchill, Resolute, and Alert. The gravimeter was kindly made available by Dr. M.J.S. Innes of the Gravity Division at the Dominion Observatory.

Dr. R.L. Christie of the Geological Survey of Canada was primarily concerned with the bedrock geology, and in 1957 carried out a reconnaissance of the Lake Hazen-Conybeare Bay area; in 1958, with his assistant, Mr. B.P. Walker, he extended his reconnaissance south-eastward to Judge Daly

Promontory, eastward to Fort Conger, north-eastward to Alert, and northward to Clements Markham Inlet. In the early part of the summer, he travelled by dog-sledge; later he used the dogs for packing. The "Dakota" aircraft was used to lay depots in Archer Fiord and at Fort Conger, and to fly the geological party to Clements Markham Inlet, whence they traversed back to Lake Hazen on what is believed to be the first crossing of the United States Range. Dr. Christie has described his work in a separate paper for the Arctic Circular.[1]

Prof. R.E. Deane of the University of Toronto was employed by the Defence Research Board during both summers to carry out research on the Pleistocene geology of the lake area and on the limnology, bathymetry and sedimentation in the lake. Four possible sites for airstrips were surveyed; the most favourable is probably the one situated about a mile west of the base camp. The ice on the lake in the spring was about 5 feet thick. In the 1957 summer the lake became completely ice-free, but in 1958 there were still about 4/10ths of ice cover west of Johns Island, although the eastern part of the lake was ice-free. Temperatures in the lake did not rise above 3°C., except in the shallow east and west ends. The glacier-fed rivers were cold, but two rivers at the east and west ends of the lake showed temperatures up to 12°C. Before the melt, the water in the lake was very clear. In the summer, muddy river water sank to the bottom, and flowed under the lake water, into the deeper parts of the basin; it gradually mixed with the clear lake water, but reached the surface only in the shallow ends of the lake. The level of Lake Hazen rises gradually during the summer through about 4 feet. Throughout the winter it slowly discharges via its only drainage, Ruggles River, and the level is gradually lowered until the following spring, when the cycle starts over again. In consequence, the upper half mile of Ruggles River remains open throughout the year. In the lower part of the river a 25-foot thick development of river ice stretches across the flood plain, through which the present river has carved a channel. Echo and line soundings over a wide area of the lake showed the greatest depth of 864 feet between Johns Island and Ruggles River. The bottom profiles slope steeply on the north side, and rise gradually towards the south side. Bottom cores up to four feet long will provide useful information on the sedimentary history of the lake. The very straight north and south shores of the lake suggest a basin which originated partly through faulting and partly through glacial erosion.

Dr. M. Brochu of the Geographical Branch of the Department of Mines and Technical Surveys, studied the sedimentology of the periglacial deposits, the glacial morphology, and the development of surface drainage and cryoconite features on Gilman Glacier. Mr. D.I. Smith, of the winter

[1] Vol. XI, No. 4, 1958 (August 1959), p. 63-6.

party, studied the geomorphology of the area. The whole area was undoubtedly covered by ice at one time. Erratics occur nearly to the summits of the mountains in the Garfield Range, indicating a considerable thickness of ice in an area which is now largely deglaciated. A very interesting exposure of apparent glacier ice, buried beneath several feet of fluvioglacial material, was found at the mouth of the river 4 miles east of the base camp and about 10 miles from the present glacier in the valley of this river. Henrietta Nesmith Glacier was found to have advanced only 5 feet between September 1957 and May 1958. Vegetation occurs right up to the snouts of the glaciers, so that there is little evidence of recent retreat, though evidence of some thinning from high strand lines above at least one marginal lake. The maximum level of marine submergence in the area, shown by marine fossils and driftwood on old beaches near the mouth of Ruggles River, was 180 feet.

Prof. J.H. Soper of the University of Toronto, employed by the Natural History Branch of the National Museum, and Mr. J.M. Powell, of the winter party, investigated the botany, plant ecology and micro-climate of the area. A total of 100 species of flowering plants were found, 35 of which also thrive on nunataks up to 3,500-4,000 feet. A few poppies were found at nearly 5,000 feet. The collection included one probable new species (a member of the Cruciferae), five first records for Ellesmere Island, and sixteen furthest north records. Soper also made a fine collection of colour slides of individual plants and plant associations.

The biology of the lake was studied by Mr. I.A. McLaren of the Fisheries Research Board. He assessed the quality and quantity of the plankton, and measured the primary production of the waters or the amount of carbon fixed by the phytoplankton. The figures for the latter were extremely low, possibly among the lowest available for lakes studied at a comparable season. He collected bottom cores from one of the small lakes near the base, where below 1 metre of sediment there was old lake ice, indicating that the cores may represent the entire sedimentary history of the lake. Much of McLaren's time was taken up with examination of over 500 Arctic Char, which thrive in the lake. They ran up to about 33 inches in length; the heaviest weighed 8 lbs. McLaren also made a collection of chironomid (midge) larvae.

The wildlife of the area was investigated by Mr. J.S. Tener of the Canadian Wildlife Service, who was primarily interested in the life-cycle and breeding of the musk-ox. He examined about 240 old skulls and made a collection of teeth for age determination by growth ring count. 71 musk-oxen, including 5 calves, were seen during the summer of 1958. Several skulls and a skeleton, found on Gilman Glacier and on nearby nunataks, showed that musk-oxen occasionally stray up the glaciers. Tener estimated the total population of the lake area at 200.

Three Peary's Caribou were seen in 1958. The wolf population on the north side of the lake appeared to be about 12, and hares were fairly common. Foxes were common and appeared to range all over the glaciers and ice cap. Lemming were very common in 1957, but extremely scarce in 1958. A small collection of certain mammals was made for the National Museum.

Dr. M.S. Maxwell of Michigan State University, employed by the Human History Branch of the National Museum, excavated archaeological sites on Chandler Fiord, Conybeare Bay, at the east end of Lake Hazen, at the mouth of the river flowing from Gilman Glacier, and at the head of Ruggles River. The latter site, which had been partially excavated by Greely in 1882, showed three stages of building - the latest occupants being an elderly man and his wife, whose partial skeletons were found. A number of sites were recorded, but not excavated, in the foothills up to 15 miles north of the lake. The archaeological sites range in age from possibly as early as the 10th or 11th century to the mid-fifteenth century. 235 artifacts were collected for the National Museum, a few of which showed certain Dorset characteristics, possibly dating back to the beginning of Thule culture. The outstanding artifact of the Ruggles River house was a walrus-ivory needle case, possibly of Alaskan design, and considered to be an heirloom handed down from generation to generation.

The geophysical programme on Gilman Glacier and the ice cap required accurate elevations and positions. The survey programme was the responsibility of Mr. K.C. Arnold, working under contract for the Defence Research Board through McGill University. It involved the running of a subtense bar level traverse from Chandler Fiord, south-east of Lake Hazen, to Clements Markham Inlet on the Arctic Ocean, a total distance of 110 miles. This traverse took two summers to complete, using dogteams, motor toboggans and pack-dogs for transport. For the northernmost leg of the traverse the survey party were landed by "Dakota" aircraft in Clements Markham Inlet, and followed Christie's trail back to Gilman Glacier. The closing error was less than 4 feet, which makes no allowance for the effect of the tides. It was also necessary to establish a triangulation network from a base line near the snout of Gilman Glacier. By means of cairns on nunataks, this network was extended up both sides of Gilman Glacier to the area of Mount Oxford. Observations from these cairns were made on about 30 stakes in order to measure the surface movement of the glacier during both summers and over the course of a full year. Surveys were also made of the snout of Gilman Glacier to assess its advance or recession. The whole survey was tied to the Geodetic Survey "Shoran" station on Johns Island.

The seismic and gravity work was carried on for the most part concurrently with the survey. In 1957, Dr. F.S. Grant, assisted by Mr. H. Sandstrom, and Mr. J.D. Filo, all of the University of Toronto, and working under contract for the Defence Research Board, concentrated on seismic work

and obtained six profiles of Gilman Glacier between the snout at an elevation of 1,300 feet and the area 10 miles east of Mount Oxford at 4,500 feet. In 1958, the seismic programme was limited to two weeks in the month of May, after which the seismic equipment was flown out. Mr. J.R. Weber of the University of Alberta, working under contract for the Defence Research Board through McGill University, assisted by Messrs. H. Sandstrom and C.R. Harington, shot a refraction profile at the Gilman Glacier camp, and a refraction and a number of reflection profiles on the highest part of the ice cap within 6 miles of Mount Oxford, where they were landed by "Dakota" aircraft at nearly 6,000 feet. Later in the summer Weber and Sandstrom carried a continuous gravity traverse along the line of the level traverse from Grant's gravity station in Clements Markham Inlet via Gilman Glacier to Mount Oxford, down Gilman Glacier and across the plateau to the Lake Hazen base camp, thence down Ruggles River to the head of Chandler Fiord. An extensive gravity survey over the whole of Gilman Glacier and on regions of the ice cap as far west as Mount Oxford was also carried out. A Worden gravimeter was used. The gravity data are being used to extrapolate from the ice thickness obtained at the seismic control points; it is hoped that the data will provide useful information on the structure of the United States Range. Reference is made to the results of the survey and geophysical work below.

For a proper understanding of the budget of a glacier, a meteorological and micrometeorological programme is essential. Mr. J.R. Lotz of McGill University, working under contract for the Defence Research Board, undertook this work in both summers. Meteorological observations were made three times a day at 0800, 1400 and 2000 for most of May, all of June and July, and for the first ten days or so of August, until the station was evacuated. Observations were made of screen temperatures, wind direction and speed, relative humidity, visibility, precipitation and cloud. Continuous thermograph, hygrograph, barograph, and sunshine records were kept. Micrometeorological work was carried on in late May, throughout June and July, and in early August, and involved making most of the above observations every two hours from 0800 to 2200. In addition, wind speed and temperature were measured at four levels up to 10 metres (33 feet) on a mast. Measurements of net radiation and short wave solar radiation were also made. The highest temperature recorded during the two summers was 46.6°F. on 25 June 1957, and the lowest -8°.9 F. in early May 1958. The 1957 summer was warmer than the 1958 summer, which was reflected in the amount of ablation at the camp - 80 cms. of ice in 1957 and 43 cms. in 1958. The prevailing wind was north-west or down-glacier. Winds seldom exceeded 10 m.p.h.; the highest were 35-40 m.p.h. in blizzards in early May 1957 and early July 1958. Work on the correlation of the various meteorological factors with the ablation in the melt season on Gilman Glacier is proceeding.

In the glaciological work, Dr. G. Hattersley-Smith was assisted in 1958 by Mr. R.B. Sagar of McGill University, working under contract for the Defence Research Board, and by Arnold and Lotz, and other members of the party in both years; work was concentrated on Gilman Glacier and on areas of the ice cap to the north and west, from which the glacier is nourished. Data were also obtained on snow accumulation and the position of the equilibrium line over a wide area extending from glaciers above Tanquary Fiord in the west, to glaciers above Clements Markham Inlet in the north-east, and northwards to the upper reaches of the glaciers above M'Clintock and Disraeli fiords on the north coast. Where possible, nunataks were visited for geological specimens and data to supplement Christie's work. The general level of the ice cap is between 6,000 and 6,500 feet with nunataks rising to 7,000 feet or higher. Mount Oxford was identified and found to be only 7,248 feet high, not 9,000 feet as stated by A.W. Moore of the Oxford University Ellesmere Land Expedtion, who climbed it in 1935. The highest mountains are situated on the flanks of the ice cap, namely between the heads of M'Clintock and Milne fiords and between the head of Tanquary Fiord and Henrietta Nesmith Glacier. The highest mountain in Ellesmere Island, and in Canada east of the Rocky Mountains, is probably in the latter area, where there is a peak reaching a height of about 8,250 feet.

Near Mount Oxford, a 6½ metre (21-foot) pit was dug, and a 7 metre (23-foot) borehole sunk from the bottom of it, for accumulation, density and temperature measurements in the firn. The snow depth here in early July was 40 cms. (15½ ins.), which is close to the average measured at 30 stations on top of the ice cap. The temperature in the firn fell rapidly from near freezing point to a steady temperature of -24°C. (-11°F.) at 3 metres (13 feet), which was maintained to the bottom of the borehole at 13½ metres (44 feet). Ice layers and density variations together were used to give an annual stratigraphy which is believed to be correct within one or two years over the past 20 years. Calculations for the years 1938-58 gave an average annual accumulation in water equivalent of 12½ cms. (5 ins.). It is significant that the lower part of the section was free of ice layers, which is believed to indicate little or no summer melting in the decade or so before 1930. Subsequent summers were marked by appreciable melting, particularly in the early 1930's and in the years since 1944.

On the north side of the ice cap, glaciers descent steeply to the trough-like valleys at the heads of the fiords, where melt-water lakes and snow-free valley sides showed that the thaw was well advanced by the end of June. These glaciers occupy valleys extending far back into the mountains, which were probably dissected by rivers in pre-glacial time; they were thus able to channel ice from the highest accumulation areas of the ice cap, and their valleys underwent powerful glacial erosion. Between Mount Oxford and the area between Yelverton and Tanquary fiords, the ice cap is by no means a flat table-top, but shows an undulating hill and dale topography with a local relief of about 400 feet. On the

south side of the ice cap the glaciers flow away much less steeply than to the north, and probably move more slowly. There are considerable variations in thickness of the ice, from 230 to 850 metres (750 to 2,800 feet) within 5 miles of Mount Oxford, indicating buried mountains.

The equilibrium line on three southward-flowing glaciers - Gilman, Henrietta Nesmith, and a glacier above Tanquary Fiord - was found to lie at an elevation of about 4,200 feet (1,260 metres), slightly higher in 1957 and slightly lower in 1958. It was judged to be at approximately the same elevation on the northward-flowing glaciers above Disraeli and M'Clintock fiords. At 4,500 feet (1,370 metres), on the upper part of Gilman Glacier, accumulation occurs by firn formation, by refreezing of slush, and by refreezing of melt water at the bottom of the snow pack. The glacier is up to 800 metres (2,600 feet) thick here, and the surface moves at a rate of about 4 cms. (1½ ins.) per day. At the Gilman Glacier camp site at 3,400 feet (1,030 metres), the glacier is about 600 metres (2,000 feet) thick, and the surface is moving at the rate of 5-6 cms. (2 ins.) per day, a movement which is maintained at least to within 2 miles of the snout, where the glacier is still 400 metres (1,300 feet) thick. The temperature distribution in the upper 25 metres (82 feet) of the glacier during the summer of 1958 was measured at the camp by thermistors; these measurements gave a mean annual temperature of -18.5°C. (-1.2°F.), or nearly 5°F. higher than at the Lake Hazen base camp for the year 1957-58.

The equilibrium line is located not far above where Gilman Glacier debouches from the ice cap. The spring snow cover in 1957 was 23 cms. (6½ cms. water equivalent), averaged at a network of ten stakes spread across the glacier about a mile above the camp; the mean depth was similar in the spring of 1958. Owing to wind action, the snow cover is appreciably less on the glaciers than on the ice cap. The mean ablation at these stakes in 1957 was 78 cms. of ice (70 cms. water equivalent), and 48 cms. of ice (43 cms. water equivalent) in 1958. In the centre of the glacier two miles from the snout and five miles below the camp, the ablation was 1.6 metres (5 feet) in 1958, and probably about 2 metres (6½ feet) in 1957. Ablation at the sides of the glacier is appreciably greater than at the centre due to the insolation at the bare rock walls. This is in part compensated by lateral spreading of the glacier measured at 6 metres (20 feet) over a width of 1,800 metres (6,000 feet) at the glacier camp between July 1957 and July 1958. The snout of the glacier has remained in roughly the same position at least for several decades, as shown by vegetation to within a few feet of the ice. The forward movement appears to be roughly compensated by the amount of melting at the snout in the summer. Preliminary calculations indicate that Gilman Glacier and its accumulation region lost roughly 20% more water through melting in the summer of 1958 than was gained by snow accumulation in the previous winter. For the budget year 1956-57 the imbalance was appreciably greater. Studies were also made of marginal, surface and tectonic features of Gilman Glacier, which are very well shown in a fine series of vertical air photographs taken by 408 Squadron in early August 1958.

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It is concluded that, on the south side of the mountains, the main glaciers - that is, those supplied from the high ice cap - are thinning in their lower reaches, but not receding at their snouts, owing to higher summer temperatures in the last few decades, as in the North Atlantic area generally. There can be no doubt that some of the small, local ice caps, which do not rise above 4,500 feet (1,370 metres), and associated glaciers, are both thinning and receding at their edges by several yards each summer. Small patches of snowdrift ice at the lower levels are disappearing from year to year. It is more than likely that similar thinning and recession is occurring on small, low level ice caps elsewhere throughout the Queen Elizabeth Islands.

It is hoped that the results of all branches of the work on "Operation Hazen" will eventually be published by the various scientists as papers in the journals, or in Government reports. Acknowledgement is made to the following for permission to refer to the field work of their officers on "Operation Hazen": the Deputy Minister, Department of Mines and Technical Surveys; the Deputy Minister, Department of Northern Affairs and Nat[illegible] Fisheries Research Board, Department of [illegible]

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